

## Assessing the Health and Performance Risks of Carbon Dioxide Exposures

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Carbon dioxide (CO<sub>2</sub>) is an anthropogenic gas that accumulates in spacecraft to much higher levels than earth-normal levels. Controlling concentrations of this gas to acceptable levels to ensure crew health and optimal performance demands major commitment of resources. NASA has many decades of experience monitoring and controlling CO<sub>2</sub>, yet we are uncertain of the levels at which subtle performance decrements develop. There is limited evidence from ground-based studies that visual disturbances can occur during brief exposures and visual changes have been noted in spaceflight crews. These changes may be due to CO<sub>2</sub> alone or in combination with other known spaceflight factors such as increased intracranial pressure due to fluid shifts. Discerning the comparative contribution of each to performance decrements is an urgent issue if we hope to optimize astronaut performance aboard the ISS. Long-term, we must know the appropriate control levels for exploration-class missions to ensure that crewmembers can remain cooperative and productive in a highly stressful environment. Furthermore, we must know the magnitude of interindividual variability in susceptibility to the adverse effects of CO<sub>2</sub> so that the most tolerant crewmembers can be identified. Ground-based studies have been conducted for many years to set exposure limits for submariners; however, these studies are typically limited and incompletely reported. Nonetheless, NASA, in cooperation with the National Research Council, has set exposure limits for astronauts using this limited database. These studies do not consider the interactions of spaceflight-induced fluid shifts and CO<sub>2</sub> exposures. In an attempt to discern whether CO<sub>2</sub> levels affect the incidence of headache and visual disturbances in astronauts we performed a retrospective study comparing average CO<sub>2</sub> levels and the prevalence of headache and visual disturbances. Our goal is to narrow gaps in the risk profile for in-flight CO<sub>2</sub> exposures. Such studies can provide no more than partial answers to the questions of environmental interactions, interindividual variability, and optimal control levels. Future prospective studies should involve assessment of astronaut well being using sophisticated measures during exposures to levels of CO<sub>2</sub> in the range from 2 to 8 mmHg.

*Learning Objectives:* Understand how gaps in the risk profile of CO<sub>2</sub> exposures are being identified; learn the complexities of potential CO<sub>2</sub> interactions with other spaceflight factors; understand how NASA uses evidence to set exposure standards for spacecraft crews.